SUPPLEMENT TO
INTERNATIONAL
JOURNAL OF
AGRARIAN AFFAIRS

DOUBLE NUMBER 1974–1975

Contributed Papers Read at the 15th International Conference of Agricultural Economists

PAPERS 1–17

Produced by the
University of Oxford Institute of Agricultural
Economics for the International Association
of Agricultural Economists

OXFORD 1975

PRICE £1.50

Mechanisation, Real Wage and Technological Change in Indian Agriculture

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Creation of new employment opportunities sufficient to absorb the currently unemployed as well as the future increases in labor force is now widely recognised as the challenge facing the developing countries of the world. Given the relatively small size of non-farm sector in these countries, it is clear that agriculture must bear much of the burden of creating employment opportunities for a long time to come. Accumulating empirical evidence in developing countries subject to "green revolution" appear to provide a basis for cautious optimism on the employment front. The new agricultural technology seems to increase employment not only as a result of increased demand for water, fertilizer, weeding, crop protection, etc., and greater multiple cropping but also indirectly through marketing and processing of larger quantities of inputs and outputs. But the simultaneous and fairly rapid rate of appearance of mechanical inputs that eventually displace labor has raised serious doubts about the employment potentialities of green revolution (see, for example, Cleaver) and aggravated the concern for employment in these countries. Attempts to rationalise farm mechanisation in the face of widespread underemployment have, not infrequently, lead to the unfounded belief that the new agricultural technology is biased in favor of mechanical inputs. Such naive inferences, when taken seriously without questioning the basis, are likely to result in unwarranted policy conclusions not excluding a death sentence on green revolution.

* See end

The purpose of the paper is to show not only that relative factor prices have played a vital role in encouraging farm mechanisation but also how the change in relative factor prices was brought about, at least in part, by technological change. That technological change lowers the prices of particular inputs relative to others is a well established fact now. But what is not generally recognised is that technological change can have, under certain circumstances, a significant impact on other factor prices as well via adjustments in factor markets. An understanding of this interrelationship between technological change and factor markets is essential since it opens up the possibility of sterilizing the "undesirable" consequences of technological change on relative factor prices and hence factor proportions without necessarily sacrificing all the benefits of new technology, through appropriate policy measures.

Empirical analysis reported below focuses attention on the impact of technological change in Indian agriculture on the agricultural labor market since, as it is shown later, wage rate was the key factor encouraging mechanisation. Also the puzzle in the Indian context is the rise in agricultural real wage despite the widespread underemployment in the country. Specifically, the paper utilizes the data for two States of India, namely Punjab and Haryana, that have witnessed a fairly rapid spread of new agricultural technology in recent years. Section I briefly reviews the extent of progress in farm mechanisation as well as the change in relative input and output prices in the two States. Section II describes the model used to explain the variations in agricultural wage rate as well as the data on which the analysis is based; it concludes with a discussion of the results obtained and areas for further

research. The last section is devoted to a discussion of the policy implications and conclusions that emerge from the study.

I. Trends in Mechanisation and Relative Prices

Table 1 presents the number of tractors and pumpsets, indicators of farm mechanisation, in the States of Punjab and Haryana as well as for all India since 1956. It is clear that farm mechanisation has been more rapid in the States of Punjab and Haryana than in the country as a whole. Since 1966, power operated pumpsets have grown much faster than tractors in India presumably in response to the spread of new high yielding varieties of seeds which are highly water responsive. It is also clear that the annual rate of growth of these two mechanical inputs, particularly in recent years, has far exceeded the rate of growth of population (2.25 percent per year) or land input (1.5 percent per year).

From table 2 it would appear that tractors have become cheaper relative to human and animal labor in recent years (See also Rao).[1] It is also clear from the table that the wage rate of agricultural labor and rural skilled workers have increased at a faster rate than all other prices during the period 1965/66 to 1970/71. Price of working animals has also shown a fairly rapid rise but of a smaller magnitude as compared to human labor. It would therefore appear difficult to reject the hypothesis that the observed trends in mechanisation were caused, at least partly, by the changes in relative input prices. Studies on tractorisation across the country also suggest a strong positive relation between relative factor scarcities and mechanisation. The number of tractors appears to have increased faster in the states which have fewer

Table 1

Trends in Farm Mechanisation

Year	Punjab and Haryana				All India			
	Tractors		Pumpsets		Tractors		Pumpsets	
	Number	Index	Number	Index	Number	Index	Number	Index
1956	3,809	100	11,896	100	20,980	100	182,963	100
1961	7,866	206	20,194	170	31,016	148	423,131	231
1966	15,489	407	55,539	467	53,439	255	969,979	530
1969	22,430	589	141,837	1192	71,100	339	1,940,357	1060
Annual rate of growth (percent):								
1956-66	15		16		10		18	
1966-69	13		37		10		26	

Source: Patel and Patel, pp. 42-43.

agricultural workers per acre and fewer working animals per acre.[2] Similarly, tractor-land ratio appears to be higher in those districts which have higher agricultural wage rates, a higher land-labor ratio, higher irrigation input per acre and higher cropping intensity (See Rao).

Price distortions could have made the tractors artificially cheaper. Prices of tractors and agricultural output among others are commonly believed to be distorted. Black market price for tractors in India far exceeded the corresponding "open market" price at least until 1970, indicating an excess demand for tractors. Overvalued exchange rate coupled with liberal import policy may have encouraged tractorisation in India (See Billings), as in the case of, say, Philippines (See Barker). With the imposition of 30 percent import duty plus 10 percent excise tax in 1971, this source of distortion is probably eliminated. But price of agricultural output supported above the competitive market price continues to have a positive influence on mechanisation among others (See Billings).

In any event, it is unlikely that the elimination of price distortions would have reversed the observed trends in tractorisation since the rise in prices of animal and human labor is much too strong to be ignored (See Table 2). A general explanation for the sharp rise in prices of inputs such as human and animal labor that are supplied from within the farming sector relative to the price of inputs supplied by the non-farm sector would appear to lie in the asymmetry of supply conditions for the two categories of inputs. With an autonomous increase in demand, inputs endogenous to the farm sector are likely to show a sharp rise in price, at least in the short run, owing to supply inelasticities; but inputs from the non-farm sector are supplied to the farms at a

Table 2

Relative Input and Output Prices in Punjab and Haryana, 1965/66 to 1970/71

Year	Punjab			Haryana					
	Harvest Wage Rate	Skilled Worker Wage Rate	Harvest Price of Wheat	Harvest Wage Rate	Skilled Worker Wage Rate	Harvest Price of Wheat	Price of Bullock (Punjab)	Price of Tractor Escorts 37 HP	All India Wholesale Price Index
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1965/66	100	100	100	100	100	100	100	100	100
1966/67	98	112	125	115	108	152	100	?	118
1967/68	123	128	123	157	116	117	103	?	133
1968/69	153	152	130	166	145	124	130	116	127
1969/70	185	187	132	182	162	122	157	?	137
1970/71	192	212		207	175		168	129	

Sources: Cols. (2), (3), (4), (8) and (10) from Statistical Abstract of Punjab (annual issues).

Cols. (5), (6) and (7) from Statistical Abstract of Haryana (annual issues).

Col. (9) from Rao, Table 5.

virtually constant supply price.[3] In the case of draft animals, however, there is an additional source of price rise, namely, the feed price. Rising opportunity costs of land and food grains, resulting from government prices policies and income and population growth, appear to have contributed to the rise in price of animal labor (See Rao).[4] But the most important factor responsible for the rise in price of animal services would appear to be the rise in wage rates since a substantial part of the maintenance cost of animals is labor charges.[5] In short, what needs to be explained is the sharp rise in price of human labor shown in table 2.

In this context, it is interesting to recall the experience of U.S. and Japan pertaining to farm mechanisation. As table 3 shows, rise in real wage appears to have played a decisive role in encouraging farm mechanisation. Rapid mechanisation did not begin until there was a sharp rise in real wages even though the real machinery price started declining much earlier.[6] In more recent periods, the evidence from developing countries such as Taiwan and South Korea also suggests that a rise in wage rate relative to other prices is a necessary condition for mechanisation.[7]

II. Determinants of Real Wage in Agriculture

The rise in agricultural wage rate in Punjab and Haryana sharply contrasts with the declining trend in real wage for India as a whole during the 1950-65 period. (See Sethuraman (1973)). Doubtless the rise in wage rate was largely due to the widespread adoption of new agricultural technology in the two states. With the introduction of high yielding varieties of wheat that are responsive to fertilizer and water in Punjab and Haryana, the demand for fertilizer and

Table 3

Trends in Mechanisation, Real Wage and Machinery Price in U.S. and Japan, 1880-1960

	U.S.			Japan		
	Tractor horsepower ('000)	Real Wage	Real machinery price	Tractor horsepower ('000)	Real Wage	Real machinery price
1880		100	100		100	100
1885		100	88		100	72
1890		129	93		84	66
1895		125	93		86	51
1900		144	82		102	50
1905		128	73		97	46
1910	18	139	66		84	39
1915	475	139	56		117	46
1920	4,920	117	38		145	51
1925	11,968	155	56		152	33
1930	21,804	184	63		161	30
1935	26,410	175	96	1.1	162	45
1940	42,300	177	86	19.5	162	41
1945	63,600	212	54	38.1		
1950	91,600	236	53	92.1		
1955	130,400	269	66	460.0	128	30
1960	159,300	345	85	3957.0	155	35

Note: Real wage and real machinery price are respectively money wage and nominal price of machinery deflated by price of agricultural commodities (crops).

Source: Derived from Hayami and Ruttan, Appendix Tables C-2 and C-3.

water has increased substantially (Table 4). Also irrigation from wells and tube wells has increased much faster than irrigation from canal sources implying greater demand for human and other sources of energy. As a result significant shifts in demand for labor and other inputs have occurred in recent years (See Billings and Singh (1971) and Clark).[8] The extent of such shifts is presumably larger in the short run for current inputs such as human and animal labor services as compared to other inputs such as tractors, land, etc., owing to the ease with which the former can be varied. Changes in demand for labor that accompanied the spread of technological change in the late sixties in Punjab and Haryana would appear to be an incomplete response to the introduction of new technology because other capital inputs, which may have an independent effect on labor demand, could not adjust themselves to desired levels. It is not clear how the labor demand will be influenced by the introduction of new technology in the true long run when all inputs are variable. It is even more difficult to predict the changes in aggregate demand for labor since the aggregate includes farms at various stages of adoption of new inputs owing to the learning process involved. Nevertheless, the available data do provide the basis for analysing the inter-relationships between technological change on the one hand and the agricultural labor market on the other.

Though these data do suggest that the new agricultural technology has significantly raised the demand vis-a-vis productivity of labor, not all the rise in wage rates can be attributed to technological change alone; factors affecting supply of agricultural labor could have contributed to the wage rate variations too. Sensitivity of labor force participation in the market to changes in wage rates suggests that the supply of labor is not totally inelastic

Table 4

Trends in the Use of High Yielding Varieties, Fertilizer and Irrigation

in Punjab and Haryana, 1965/66 to 1970/71

Year	Punjab				Haryana			
	Area Under HYV Wheat ('000 ha)	Fertilizer Consumption (material) ('000 tonnes)	Gross Irrigated Area ('000 ha)	Net Area Irrigated by Wells ('000 ha)	Area Under HYV Wheat ('000 ha)	Fertilizer Consumption NPK ('000 tonnes)	Gross Irrigated Area ('000 ha)	Net Area Irrigated by Wells ('000 ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1965/66		236	3135	887		13.63	1483	224
1966/67		237	3366	982		13.35	1736	289
1967/68	621	385	3464	989	100	32.47	1780	227
1968/69	1194	581	3823	1352	256	47.02	1864	385
1969/70	1502	534	4086	1530	440	53.92	2158	437
1970/71	1497				600	77.53		

Sources: i) Statistical Abstract of Punjab (annual issues)

ii) Statistical Abstract of Haryana (annual issues)

with respect to wage rate. Demand for labor from industries growing in the countryside of Punjab and Haryana would also appear to influence the supply of agricultural labor via the non-agricultural wage rate that a potential migrant from the villages can expect. In general, it is important to recognise the presence of shift variables that cause shifts in the supply as well as the demand functions for agricultural labor.

These considerations together with the assumption of perfect competition and constant returns to scale in the production of crops yield the following simple model for wage determination in the agricultural labor market in the short run.

(1) Demand: $WA = f(Py, HYV, F, L^d/I, B, A, T)$

(2) Supply: $WA = g(WNA, L^s, N, Y, M)$

(3) Equilibrium: $L^d = L^s$

Where WA = Wage rate of agricultural labor;

WNA = Wage rate of non-agricultural labor;

Py = Price of output in agriculture;

HYV = Area under high yielding varieties, an index of the rate of adoption of new technology;

F = Fertilizer consumption;

I = Gross irrigated area;

L^d = Aggregate demand for labor;

B = Number of working animals;

A = Land (cropped area);

T = Number of tractors;

L^s = Aggregate supply of labor;

N = Potential labor force;

Y = Per capita agricultural income and/or per capita gross domestic product in non-agricultural sector; and

M = Net out-migration of labor.

The above model assumes instantaneous adjustment of wage rate to excess supply/demand in labor and is essentially concerned with the short run situation; it ignores the lags in adjustment. Equation (1) also assumes that capital inputs such as irrigation, working animals, land, and tractors remain constant at their current levels in the short run for reasons noted earlier. This simple simultaneous equation model with wage rate and labor as two endogenous variables is assumed to describe the rural labor market in India well.

Since the main interest of the paper is to identify the contribution of technological change and other factors to the observed increases in agricultural wage rates and thus explain the variations in wage rate rather than estimate the demand and supply functions of labor as such, attention is focused in what follows on the reduced form equations of the model above. Of course, it is possible to estimate the structural parameters of the model from the estimated coefficients of the reduced form equations provided data are available on all the relevant variables. Unfortunately data on the important variable, the quantity of labor employed, are not available; difficulties in measuring it at the aggregative level are well known. Thus, the empirical results reported below are based on the reduced form equation relating wage rate of agricultural labor to all the exogenous variables of the model specified above.[9]

Data used for the regression analysis are mostly drawn from the statistical abstracts of the states of Punjab and Haryana. The analysis is based on the time series -- cross sectional data from 11 districts of Punjab for the period 1965/66 through 1970/71 and 7 districts of Haryana for the period 1967/68 to 1969/70.[10] Data considerations dictated several compromises on the variables available for estimating the above model. Wage rate of non-agricultural labor in rural areas is used in the regression analysis though ideally it is desirable to use the typical (non-agricultural) wage rate in urban areas that a potential migrant from rural areas can expect (See Minami). Similarly the 1971 Census figures on total rural workers, which actually represents the 'stock' of work force, is used as a proxy for the potential labor force.[11] Lack of reliable data on 'per capita domestic product in non-agricultural sector' and 'per capita agricultural income' for each district for each year led to the deletion of these variables from the estimated equations. On the demand side, area under high yielding varieties (HYV) and price of output pertain to wheat alone since it is the most important crop subject to technological change and price policy, in the two states; and also it eliminates the error due to aggregation bias that might creep in through the inclusion of other crops. Finally, though it was possible to include alternative irrigation variables in the equations, fertilizer had to be deleted in order to avoid the multicollinearity problem arising out of its high correlation with the area under high yielding varieties.[12]

In estimating the reduced form equation it is assumed that the random disturbance term is independently distributed with zero mean and finite variance. Equations were estimated both in original and logarithm versions of the

variables but the former estimates were deleted from the following presentation since in every case it showed a relatively poor fit to the data. To assess the impact of 'weather' and 'region' on the wage rate, year and state dummies were defined and included in the regressions.[13]

The estimated coefficients of the reduced form equation explaining the wage rate of agricultural labor are presented in Table 5.[14] The explanatory variables included explain as much as 72 percent or more of the variations in agricultural wage rate. Though it is not possible to infer the magnitude of structural parameters, the estimated coefficients do provide indications about the nature of the 'shifts' in demand and supply functions as well as the relative importance of included explanatory variables. All 'shifts' are in the expected directions with the exception of 'net irrigated area from wells'. Area under high yielding varieties on the demand side and Non-agricultural wage rate and total rural workers are the most significant explanatory variables on the supply side; the most significant variable on the demand side is the area HYV. Number of tractors appears to have a positive effect on the agricultural wage rate but is not statistically significant.[15] This is consistent with the experience in other countries such as U.S.A., Japan, Taiwan, etc. where the number of farm workers did not decline with the spread of mechanisation until after a long period.[16] It also makes sense since, in the initial stages of mechanisation, only a selected few agricultural operations are mechanised and labor demand does not decline immediately. Further, the absolute number of tractors in each district is still small relative to the amount of land and labor used. Similarly number of working animals also appears to have a positive but not statistically significant effect on the wage rate presumably

Table 5

Determinants of Wage Rate in Agriculture

Number of observations: 85

Dependent Variable: Wage rate in agriculture

Equation no.	(1)	(2)	(3)
1. R^2	0.72	0.74	0.72
2. Constant	-16.853	-16.114	-2.923
3. Price of output	5.326*	5.292*	1.823
	(2.394)	(2.366)	(1.885)
4. Area under HYV	0.217**	0.195**	0.096
	(0.058)	(0.061)	(0.056)
5. Number of tractors	0.077	0.065	0.102
	(0.052)	(0.052)	(0.058)
6. Number of working animals		0.102	0.176
		(0.146)	(0.218)
7. Gross irrigated area			0.040
			(0.074)
8. Net irrigated area from wells	-0.096*	-0.082*	
	(0.038)	(0.038)	
9. Number of private tube wells			-0.023
			(0.030)
10. Net sown area	0.148		
	(0.107)		
11. Total cropped area		0.321*	0.320
		(0.156)	(0.208)
12. Non-agricultural wage rate	0.447*	0.446*	0.395*
	(0.182)	(0.180)	(0.184)
13. Total rural workers	-0.432**	-0.676**	-0.752**
	(0.130)	(0.238)	(0.261)
14. Year dummy for 1970/71	-0.754**	-0.717**	-0.207
	(0.253)	(0.251)	(0.158)
15. Year dummy for 1969/70	-0.920**	-0.879**	-0.258
	(0.315)	(0.312)	(0.196)
16. Year dummy for 1968/69	-0.893**	-0.846**	-0.242
	(0.310)	(0.308)	(0.193)
17. Year dummy for 1967/68	-0.738**	-0.711**	-0.224
	(0.248)	(0.245)	(0.158)
18. Year dummy for 1966/67	-0.767**	-0.739**	-0.262
	(0.260)	(0.258)	(0.175)

**Significant at 1 percent level *Significant at 5 percent level

Note: All except dummy variables are measured in logarithms.

suggesting a weak partial substitutability between animal and labor in the production of crops.

Total cropped area has a positive and significant effect on wage rates as expected. The negative and statistically significant coefficient of 'net irrigated area from wells' is puzzling because irrigation from wells increases demand for labor, other things equal.[17] The negative effect of tube wells on the wage rate is shown in regression (3) where the gross irrigated area is held constant. But none of the irrigation related variables are significant probably due to the presence of area under high yielding varieties in all the equations; much of the effect of irrigation is already picked up by the variable 'area under HYV'. The coefficient of the price of output is positive and surprisingly high, where it is significant. It implies that every one percent increase in price of wheat increases the wage rate by more than 5 percent; or, in absolute terms, increase in price of wheat per quintal by one rupee leads to increase in wage rate per day by 40 paise at the mean level, other things equal. This may, at least partly, be due to smaller variations in price variable relative to the agricultural wage rate. Finally, it is interesting to note that all the year dummies which presumably reflect the weather effect are highly significant and negative and belong in the equation. Bulk of this negative effect pertains to the year 1966/67, which was a drought year; if we exclude this, the marginal effect of other years appears to be small. These results pertain to the short run situation; it is not clear how they will be altered when lags in adjustment of capital inputs are also taken into account.

Nevertheless, these results imply that much of the rise in agricultural wage rate in Punjab and Haryana was caused by the spread of high yielding

varieties (which includes fertilizers and irrigation as well) and increase in non-agricultural wage rate because these two variables have a sizeable positive effect on agricultural wage rate and these are the variables that have shown a rapid rise in recent years.[18] With the exception of tractors, most other variables in the equation have shown relatively little increase during the period 1965/66 to 1970/71. Given the average annual increase of 14 percent in non-agricultural wage rate and 43 percent in the area under high yielding varieties, the model predicts a rise in agricultural wage rate of 14.9 percent per year from these two sources alone in the two states combined, while the actual increase was about 15 percent per year. The empirical results presented above would appear to suggest that most of the observed increases in agricultural wage rate in Punjab and Haryana in recent years were caused by two factors: spread of high yielding varieties and rise in non-agricultural wage rate. The highly significant negative coefficient of total rural workers (an index of potential rural labor force) suggests that in- and out-migration of labor in Punjab and Haryana agriculture will have a significant influence on the movement of agricultural wage rate.

III. Policy Implications and Conclusions

The above analysis emphasizes change in relative prices as the key determinant of farm mechanisation. Expected changes in relative prices, technology and institutional setup such as land tenure systems and labor unions may have also contributed to farm mechanisation. More importantly, if the technology of production is variable, it is unrealistic to assume that the technical elasticity of substitution between labor and machines will remain constant.

Thus, changes in the elasticity of substitution could have contributed to the observed trends in mechanisation too in India. But empirical evidence supporting the view that the new agricultural technology has altered the elasticity of substitution between tractors and labor is lacking.[19] In the absence of such evidence it is difficult to accept the verdict that the new technology of crop production is 'biased' in favor of mechanisation in the conventional sense. It does not follow, however, that farm mechanisation is unrelated to the adoption of new technology. On the contrary, empirical evidence available for India, Philippines and other countries clearly indicate that the new agricultural technology is most profitable when the different agricultural operations are performed at the appropriate time[20] and mechanisation facilitates such timely operations. By virtue of its characteristics such as shorter crop season and photoperiod insensitivity of the new varieties, multiple cropping is made feasible by the new agricultural technology, provided the fields are cleared, plowed and planted at the right time. Thus, while the new technology releases the much needed land resource (particularly when ceilings on land holdings are effective) for multiple cropping it simultaneously increases the demand for animal and human labor in the peak season(s) resulting in a sharp rise in their prices in those periods. (See Billings and Singh (1971)). Also, multiple cropping raises the rate of return on tractors through reduced underutilization of the machines. As a result, there is a tendency to mechanise farms with the adoption of new agricultural technology; the incentive for mechanisation being provided, once again, by changes in relative factor prices.

Another excluded determinant of farm mechanisation is the size of farm. Empirical evidence in India, Pakistan, Philippines and elsewhere suggest that

farm mechanisation is not neutral with respect to scale. Capital market imperfections and indivisibility of tractors are cited as important factors explaining the adoption of tractors by large farms. The process of adoption of new technology (including tractors) itself appears to be sensitive to scale factors since it involves acquisition of 'new knowledge' which in turn is not neutral with respect to scale.[21] Again, since the adoption of new agricultural technology encourages, and mechanisation facilitates, multiple cropping for reasons already discussed, size of farm, adoption of new technology and mechanisation appear to be strongly co-related (See Staub). But one of the major motivating factors for farm mechanisation by large farms (measured in terms of farm size), not often recognised, would appear to be the rise in price of labor because these farms heavily depend on hired labor. Size distribution of land holdings would therefore appear to be an important variable explaining the pace of farm mechanisation; but at least a part of its influence can be traced to changes in relative factor prices resulting from the introduction of new technology. In the long run, however, when all farms have had sufficient time to adjust to the optimal factor proportions and tractors become available in all sizes, the scale factor associated with the adoption of tractors is likely to fade out, if not disappear.[22]

The above discussion points out that economies of scale may have played an important role in farm mechanisation. But much of the effect of technological change on farm mechanisation seems to be transmitted through changes in relative factor prices; thus it reinforces the role of relative price changes in inducing farm mechanisation. Prices of animal and human labor in particular seem to have played a vital role in inducing mechanisation in India, as in the

case of other developed and developing countries. Empirical evidence relating to the determinants of agricultural wage rate presented in the last section offers several interesting policy implications and conclusions.

First, the results indicate that much of the rise in wage rate in recent years was due to the spread of new agricultural technology and a sharp rise in non-agricultural wage rate. These findings support the hypothesis that the new agricultural technology comprising high yielding varieties, irrigation and fertilizers has made a significant contribution to the labor productivity in Indian agriculture. It also implies that the new technology substantially increased the demand for agricultural labor, other things equal.[23] Thus, the new agricultural technology, while capital using, is also highly biased in favor of labor. Second, the evidence suggests that, unlike in U.S. and Japan for example, much of the rise in real wage necessary to induce mechanisation came from technological change within agriculture rather than through 'pull' factors operating in non-agricultural sectors. It does not follow, however, that agricultural wage rate in India is insensitive to similar forces or that such forces are absent. On the contrary, the empirical results of this study clearly show how sensitive the agricultural wage rate is to non-agricultural wage rate and in- and out-migration of labor from agriculture. Finally the study demonstrates how technological change can have significant effects on factor markets and, hence their prices, which in turn affects the factor proportions. It shows that the missing link between the adoption of new technology and mechanisation of farms is the relative price changes.

Recognition of this interrelationship between technological change and factor prices suggests several policy implications. It is possible to

discourage mechanisation without hurting the spread of new agricultural technology through policy measures designed to neutralize the impact of the latter on relative input prices. One policy measure suggested by the results of this study is to encourage in-migration of labor sufficient to prevent sharp increases in farm wage rate since it appears from Table 5 that every 10 percent increase in potential labor force is likely to result in a reduction of 4 to 7 percent in the agricultural wage rate, other things equal. However, given widespread underemployment in areas adjacent to Punjab and Haryana one wonders why there has not been an in-migration of labor sufficient to prevent a rise in agricultural wage rate.[24] In addition to skill differences, language and cultural barriers are two inhibiting factors. However, more important may be the fact that the wage differential is not sufficient to compensate the costs of migration,[25] particularly when such jobs are available only for short durations during specific 'seasons' in a year. A public policy to encourage such migration through appropriate subsidies is possible; but there are obvious limitations on the extent to which such migration can be encouraged since any large in-migration will have severe political and social consequences. Under these circumstances, the only other policies that could prevent further farm mechanisation are: 1) those that prevent the spread of new agricultural technology by making the seed, fertilizer and irrigation inputs more expensive and/or 2) those that make the mechanical inputs more expensive. It is generally recognised that the latter course is desirable since it brings about the desired factor proportions without eliminating the benefits of the new agricultural technology. Imposition of import duty and excise tax on mechanical inputs in India and elsewhere in recent years would appear to be a move in this direction.

However the basic question remains: if migration of labor to prevent farm mechanisation is not feasible why should there be a concern for mechanisation, particularly when it takes place in response to rising wage rate? Farm mechanisation does not cause any concern in developed countries where full employment conditions prevail and labor is relatively more expensive than capital. The concern for farm mechanisation would then appear to emerge from the concern for equity. It is argued that use of tractors, owing to its indivisibility, tends to increase the demand for land which in turn will wipe out smaller farms that are not mechanised. It is also argued that with increase in scale of operation coupled with a modern mechanical technology, the unit cost of production of large farms will reduce and thus eliminate smaller farms from competition. Insofar as mechanical inputs are divisible and hence neutral to scale, this argument is weakened.[26] Similarly, development of a market for tractor services, which is common in parts of India, Thailand and the Philippines, would appear to weaken this argument too.[27] More important, however, is the ceilings on landholdings imposed by law; if enforcement of such laws is possible and feasible through a suitable administrative machinery, then the efforts to prevent mechanisation are not meaningful on this count. Presumably, under these conditions, farms will choose not the mechanise unless it is profitable to do so without increasing the size of the holding.

The study has also some long run implications for the generation of new technologies in the future. It underlines the need for recognising the rigidities and limitations operating on the supply side of various factors of production in evolving the new technology since each technology has its own factor bias. The study also offers some insights about the spread of farm

mechanisation in other parts of India and elsewhere. While it is clear that the spread of new agricultural technology tends to increase the demand for both labor and capital, it is unlikely to encourage farm mechanisation insofar as there exists a pool of underemployed with the result agricultural wage rate shows little or no rise.

Footnotes

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1. It is interesting to note that similar trends in relative factor prices seems to have prevailed in Philippines and Korea too. (See Barker and papers on Korea in Southworth)

2. See Sethuraman (1972) and references cited therein.

3. This is particularly true since the demand for non-farm inputs in a given region such as Punjab and Haryana is but a small part of the corresponding aggregate demand for the country as a whole. Further the mobility of factors such as animals and human labor between regions is limited for reasons discussed later.

4. Also variations in seasonal pattern of demand for animal labor could have a significant effect on the rental on working animals. See Billings and Singh (1971) for the impact of new agricultural technology on seasonal pattern of demand for animal labor in Punjab and Haryana.

5. See Sethuraman (1970), Appendix Table 13.

6. As a matter of fact from Griliches' work we know that the rate of increase in tractor power and the decline in its real price for the U.S., shown in table 3, are underestimates.

7. See the papers on Taiwan, Korea and others in Southworth.

8. See Barker for a similar discussion of the impact of new agricultural technology on labor demand, etc., in Philippines too.

9. Alternative equations including 'cropping intensity' and 'factory employment in the countryside' (the latter as a proxy variable for out-migration of labor) were also estimated; since they did not increase the explanatory power of the equations significantly they are not reported here. Poor performance of the variable 'factory employment' is probably because the data exclude small factories with under 10 workers.

10. However, the number of observations available for analysis was 85 instead of 87 since the data for one district were not available for two years.

11. Total rural workers for other years are based on interpolation using the annual rate of growth. Similar procedure was adopted for the number of working animals too, since annual data are unavailable.

12. See table 4 and also the evidence cited in Rao.

13. Since the state dummy was not significant in any of the estimated equations it was dropped later.

14. Throughout this analysis wage rate of agricultural labor means harvest wage rate; since the wage rate for plowing, sowing, seeding, etc. are highly correlated with harvest wage rate use of the latter as a dependent variable does not bias the results significantly.

15. Some studies based on farm management data in India have also found that the influence of tractors on employment is statistically not significant.

16. See for example papers in Southworth and Hayami and Ruttan.

17. What it does reflect may be the effect of tube wells, which are not held constant in regression equations (1) and (2).

18. Minami (pp. 193-194) found a large positive and highly significant coefficient for non-agricultural wage rate in explaining the out-migration of labor from agriculture in Japan for the period 1922-1961.

19. It is sometimes claimed that the use of tractors could result in a better seed bed preparation leading to 'fewer weeds, better moisture control, better distribution of basal fertilizer dressing and higher germination.' (Billings and Singh (1970, p. 82)); but strong evidence to support this claim is lacking.

20. See Barker and Billings and Singh (1971), for example.

21. See, for example, Sethuraman (1968).

22. In addition to those discussed, non-economic factors such as the prestige value of owning a tractor are also recognised by some writers in explaining farm mechanisation in developing countries.

23. Unfortunately no data are available on aggregate employment before and after the introduction of new technology. The results obtained in this study would seem to imply that there has been a 'net' increase in demand for labor and hence employment; but this observation needs further confirmation.

24. It should be noted that there has been significant in-migration of labor from neighbouring areas in recent years.

25. See Sjaastad for a list of various costs and benefits associated with migration.

26. Production of smaller tractors than were available hitherto in India is a real possibility.

27. Large farmers in parts of India are known to rent out tractor services to smaller farmers.

References

R. Barker et al., "Employment and Technological Change in Philippine Agriculture," International Labour Review, Aug.-Sept. 1972, 106, 111-139.

M. Billings, "Tractor Subsidization Practices in India and Other Less Developed Countries," USAID, New Delhi 1972 (Mimeo.).

_____ and A. Singh, "Farm Mechanisation and the Green Revolution, 1968-84: The Punjab Case," USAID, New Delhi 1970 (Mimeo.).

_____ and A. Singh, "The Effect of Technology on Farm Employment in India: A Long Term Perspective," in H. Lubell and R. G. Ridker (ed.), Employment and Unemployment Problems of the Near East and South Asia, Delhi 1971.

C. Clark, The Economics of Subsistence Agriculture, 4th ed., New York 1970.

H. Cleaver Jr., "The Contradictions of the Green Revolution," Amer. Econ. Rev., May 1972, 62, 177-186.

Y. Hayami and V. W. Ruttan, Agricultural Development: An International Perspective, Baltimore 1971.

R. Minami, "Population Migration Away from Agriculture in Japan," Economic Development and Cultural Change, Jan. 1967, 15, 183-201.

S. M. Patel and K. V. Patel, "Progress of Farm Mechanisation in India," in Problems of Farm Mechanisation, Seminar Series IX, Indian Society of Agricultural Economics, Bombay 1972.

C. H. H. Rao, "Farm Mechanisation in a Labour Abundant Economy," Economic and Political Weekly, Feb. 1972, 7, 393-400.

S. V. Sethuraman, "Economics of the Process of Adoption of New Techniques," Univ. Chicago, 1968 (mimeo.).

_____, "Long Run Demand for Draft Animals in Indian Agriculture," unpublished doctoral dissertation, Univ. Chicago 1970.

_____, "Implications of Mechanisation in Agriculture to Employment and Income Distribution in Rural Areas: A Review," USAID, New Delhi, June 1972 (mimeo.).

_____, "Employment and Labor Productivity in India Since 1950," Economic Development and Cultural Change, 1973 (forthcoming).

L. A. Sjaastad, "Costs and Returns of Human Migration," J. Polit. Econ., Supplement, Oct. 1962, 70, 80-93.

H. Southworth, Farm Mechanisation in East Asia, New York 1972.

W. J. Staub, "Agricultural Development and Farm Employment: An Analysis of Factors Influencing the Employment of Family, Permanent and Casual Labor on Farms in Two Developing Districts in India," unpublished doctoral dissertation, Univ. Missouri 1971.

Government of Punjab, Statistical Abstract of Punjab, Chandigarh.

Government of Haryana, Statistical Abstract of Haryana, Chandigarh.